Experimental Study of Gap Distance between Floating Structures in Tandem Arrangement

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ABSTRACT

This research is proposed to study the effect of wave condition to the distance between floating structures which arranged in tandem arrangement. The evaluation on the gap distance between floating structures is an important study for offshore liquefied natural gas, LNG offloading system because small gap distance between floating structures is needed to guarantee the effectiveness of LNG transfer from FPSO to ship but collision between floating structures should be avoided. Therefore, the gap distance between floating structures becomes a main factor to ensure the safety of the arrangement and effectiveness of the offloading system. Model experiment in regular wave condition was carried out to analyze the motion of floating structures and the effect of wave on changing of gap distance between structures. The time domain motion data are measured by Qualisys Camera and then Fourier Transformation method is applied to transform the data to frequency domain for further analysis. The frequency domain data is utilized in this research to find the tendency of gap distance between floating structures due to the effect of structures response and wave condition. From the study, an empirical equation to simulate the minimum gap distance between floating structures is introduced.

KEY WORDS: *Gap Distance, Floating Structures, Motion.*

NOMENCLATURE

LNG	Liquefied Natural Gas
FPSO	Floating Production Storage Offloading
HOBEM	Higher-Order Boundary Element Method
FLNG	Floating Liquefied Natural Gas
DOF	Degree of Freedom
TLP	Tension Leg Platform

1.0 INTRODUCTION

The number of offshore exploration activity in deep water area is increasing now day due to reduce of natural source in land or near shore area. In deep water area, floating structures are only alternative to apply for the oil and gas exploration process. However, the motion of floating structure is easily influence by wave and this arise a safety issue especially in multiple floating structure system. During LNG offloading process, the FPSO and ship is required to arrange in small distance to ensure the effectiveness of the offloading process. Hence, the study of the gap distance in multiple floating structures becomes important to ascertain the safety of the structures arrangement and avoid of accident to occur.

Response of structures to environment at open water is an important criterion required to evaluate to ensure the system operates safely. The comparison between single floating structures with multiple structures made by Siow et al. showed that the hydrodynamic interaction effect may cause the floating structures to experience larger motion amplitude in all six types of motion [13]. This phenomenon can cause accidents on floating structures such as crash between structures. Therefore, multi structures operation should give more attention during design and it requires more accurate analysis of hydrodynamic interactions between closely moored structures [6].

To avoid collision occur in multiple floating structures system, the proper arrangement of the floating structures is required. One of the factors must evaluate in structures arrangement is the distance between floating structures. The ocean wave is one of the energy sources to generate the motion of floating structures. The gap distance between floating structures is changed depend on the motion of both floating structures from time to time. This causes the study of the influence of structures motion to reduce of the distance between structures respect to the original distance become significant important to avoid accident occur.

To understand changing distance between floating structures due to the motion induced by wave, Siow et al studied theoretical concept on the effect of structure motions to the reduce of gap distance between floating structure and conduced an experimental study [24, 25]. In this research, the analysis of influence of wave to the minimum distance between structures is focused. The mentioned minimum gap distance in this paper mean minimum distance between two floating structures achieved due to surge motions induced by wave. To study this, the semi-submersible and TLP models are selected and arranged in tandem arrangement. The model experimental is conducted from wavelength around 2 meters to 9 meters. The analysis is made to obtain the relationship between minimum gap distance between both the selected structures to the effect of structures' motion response and wave condition.

2.0 LITERATURE REVIEW

Matos et.al commented that the vertical plane motions induced by heave, roll and pitch should be kept adequately low to guarantee the safety of the floating structure, risers and umbilical pipes and other important facilities use in oil production [22]. The operability and safety of floating bodies operation are greatly determined by the relative motions between them. So, the accurate motion prediction of two bodies included all the hydrodynamic interaction is greatly important [10].

Motions of floating structures can be analysed by applying strip theory and potential theory. A number of notable studies were carried out to study hydrodynamic interaction phenomena such as Ohkusu[12] and Kodan[9].

Hess and Smith [5], Van Oortmerssen[17] and Loken[11] studied on non-lifting potential flow calculation about arbitrary 3D objects. They utilized a source density distribution along the structure surface and solved for distribution necessary to lake the normal component of the fluid velocity zero on the boundary. Also, Wu etal.studied the motion of a moored semi-submersible in regular waves numerically and experimentally. In their mathematical formulation, the moored semi-submersible was modeled as an externally constrained floating body in waves, and derived the linearized equation of motion [18].

Yilmaz and Incecik analysed the excessive motion of moored semi-submersible. They developed two different time domain techniques due to mooring stiffness, viscous drag forces and damping; the mathematic models are strong nonlinearities in the system. In the first technique, first-order wave forces acting on a structure which considered as a solitary excitation force and evaluated by using the Morison equation. In the second technique, mean drift forces were used to calculate slow varying wave forces and simulate slow varying and steady motions [19]. Söylemez developed a technique to predict damaged semi-submersible motion under wind, current and wave. An approaching equation of motion based on Newton's second law was used in the research to develop a nonlinear numerical technique for both intact and damaged condition in time domain [14].

Besides, the hydrodynamic interaction effect was studied by Kashiwagi. He introduced a hierarchical interaction theory in the framework of linear potential theory used to study hydrodynamic interactions between a large numbers of columns supporting flexible structure. He also furthers the research to investigate wave drift force and moment on two side by side arranged ships by using Higher-Order Boundary Element Method (HOBEM). His research obtained that the hydrodynamic interaction force is more predominant in the motion equation in the shorter wavelength region due to resonant phenomena. Kashiwagi was also concluded that the intensity of the interaction force is dependent upon the ratio of the wavelength to the separation distance between two adjacent cylinders. After that, Kashiwagi was also investigated the applicability of wave interaction theory apply to simulate the small gap length condition. The study obtained that the wave interaction theory able to predict the motion accurately if the separation between the structures is satisfied with the addition theorem of Bessel functions [8].

Besides, Choi and Hong were also applied HOBEM to analysis hydrodynamic interactions of multi-body system [3]. Clauss et al. analyzed the sea-keeping behavior of a semi-submersible in rough waves in the North Sea by numerical and experimental method. They used panel method TiMIT (Time-domain investigations, developed at the Massachusetts Institute of Technology) for wave-structure interactions in time domain. The theory behind TiMIT is strictly linear and thus applicable to moderate sea condition only [4].

On the other hand, Spyros was also purposed a design oriented semi-analytical method to solve the radiation problem and evaluate the hydrodynamic and interaction coefficients [15]. An analytical solution to solve hydrodynamic diffraction problem of arrays of elliptical cylinders were also introduced by Ioannis and Spyros [7]. In the research, he obtained that the variation of hydrodynamic loading on the interaction cases is in relative to the wave heading angle. Besides, the effect of structures numbers affects to hydrodynamic interaction was also covered by Tajali et al. [16]. Their research results indicated that by increase the number of pontoons can cause the peak frequency and peak amplitude for all motion increase.

A numerical method also employed by Zhu et.al to study the effect of gap in multiple box shape structures system. In that study, the potential for incident wave and scattering wave were ignored, the motion of the structures is assumed only affected by radiated wave [21]. The gap distance was ranged from 1% of breadth to 50% of breadth. The simulation showed that the hydrodynamic interaction between floating structures can caused by the surge, sway and heave motion; however, only sway motion shows a strong interaction at certain resonance wave number. And then, Zhu et al. also conducted a research on hydrodynamic resonance phenomena of three dimensional multiple floating structures by applying linear potential theory in time domain. The gap was limited to 1% compared to the breadth. The research found that peak force response on floating bodies at resonance frequency is same between frequency domain technique and time domain technique. This proved that the time domain technique can be an alternative to investigate hydrodynamic interaction phenomena between floating bodies in small gap [21].

Zhao etal. was carried out a study of hydrodynamic interaction between FLNG vessel and LNG carrier which arranged in side by side arrangement. They were observed that the hydrodynamic interactions give more influence to the surge, sway and yaw motions. In addition, they also discovered that the interaction between structures able to affect the load on the structures connection systems [20].

In addition, few experimental tests were carried out to obtain the motion response of structures. A model test related to interaction between semi-submersible and TLP was carried out by Hassan Abyn et al [1]. In continue Hassan Abyn et.al also tried to simulate the motion of semi-submersible by using HydroSTAR and then analyze the effect of meshing number to the accuracy of execution result and execution time [2]. Besides that, K.U. Tiau was simulating the motion of mobile floating harbor which have similar hull form as semi-submersible by using Morison Equation [23]. To investigate the interaction effect to structures motions, C. L. Siow et.al were made a comparison on the motion of semi-submersible when it alone to interaction condition by using experimental result [13].

To evaluate the effect of the motion to the change of distance between floating structures, the conceptual study was carried out by Siow et.al [24]. This study obtained that the wavelength and the initial distance between floating structures are the main factors influence the minimum distance possible to achieve by the floating structure. The experimental study of minimum gap distance between floating structures also conducted by Siow et al. to propose an empirical equation which can use to define the minimum achievable distance between floating structures when the motion is induced by wave [25].

From the series of reviews, it obtain that a lot of effort was made by many researchers to study the hydrodynamic interaction phenomena. The literature review also shown that the previous research on this area are preferred to study on the effect of hydrodynamic interaction to wave forces acting of structures, change of hydrodynamic coefficient and structures motion in response to wave. To improve the safety of the multiple floating structures system which arranged in small gap distances, this research is proposed to evaluate the change of the gap distance due to the motion of floating structures which induced by wave.

3.0 MODEL EXPERIMENTAL

In this study, model experiment was conducted to study the minimum gap length of the floating structures arranged in small gap. The experiment was made at UTM's towing tank. The long, wide and deep for this towing tank are 120m, 4m and 2.5m. In addition, gravity wave can be generated by this tank has the range of wave period from 0.5 to 2.5 sec with maximum wave heights 0.44m. The experiments were conducted for the conditions where the semi-submersible arranged behind the TLP structure. The distance between both structures in model scale is 310 mm in this experiment tests.

3.1 Models particulars

In this experiment, the semi-submersible model was constructed based on GVA 4000 type model. Both the semi-submersible and TLP model were scaled down with ratio 1:70.

Upon the model completely constructed, inclining test, swing frame test, oscillating test, decay test and bifilar test were carried out to identify the hydrostatic particular for both the semi-submersible and TLP. Results collected from there tests were summarized as in table 1.

Table 1: Principal particular of Models

Character	TLP	Semi	Unit
Length	57.75	66.78	m
Width	57.75	58.45	m
Draft	21	16.73	m
Displacement	23941	14921	m^3
Water Plan Area	715	529.6	m^2
Number of Columns	4	4	
Pontoon length	31	66.78	m
Pontoon depth	7.28	6.3	m
Pontoon width	9.73	13.3	m
Pontoons centerline separation	-	45.15	m
Columns longitudinal spacing (centre)	-	45.58	m
Column diameter	-	10.59	m
GM_T	7.77	2.87	m
GM_L	7.63	4.06	m
K_{XX}	26.11	31.64	m
K_{YY}	26.46	26.95	m
K_{ZZ}	30.8	35	m
CG_Z	-6.37	-0.28	m

3.2Motion tests

The floating structures were assumed to experience six degrees of freedom. The six DOF motions of the models were moored on springs and measured by optical tracking system (Qualisys Camera).

Water-proof load cells are attached to the springs at the model fairlead locations to measure applied tension force on the model from the mooring springs directly. The purpose of this setup is to avoid any losses in force. Lightweight ring gauge load cells used here are sufficiently sensitive to provide a good signal for small mooring line tensions. The measured mooring line tensions are recorded by Dewetron Data Acquisition System (DAQ).

Due to the limitation of this tank, the tendons, risers and moorings are not actually presented in the model tests. Therefore, this model setup was expected had less damping and caused larger motion amplitude at model scale compared to the prototype.

Soft lateral springs were attached to the TLP and Semi-submersible to give horizontal restoring force to prototype TLP tendons and Semi-submersible moorings. One Side of the soft lateral spring was clamped to the mooring posts attached to the carriage and other side of the ends was connected to load cells at model side to measure the spring tension forces at the model. Anchor locations for the springs were proper selected to ensure mooring lines of the model make 45 degree angle with respect to the fairlead attachment points on the model. The spring pretension and spring stiffness applied in the test was same as horizontal stiffness required for the system to match the natural periods of the horizontal motion (surge, sway) for the TLP and Semi-submersible. Due to limitation of water deep, almost horizontal springs set considered for compensation of horizontal forces (Figure 1). Also, the TLP and Semi-submersible are connected between each other by two connectors to control the gap between the floating bodies (Figure 2).

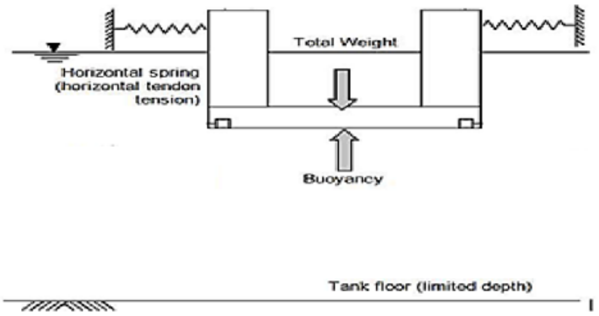

Figure 1: Model test set-up in available water depth

Hydrodynamic interaction between floating structures model test for TLP and Semi-submersible was set up as shown in figure 2. In the arrangement, progressive wave firstly attached TLP model before semi-submersible.

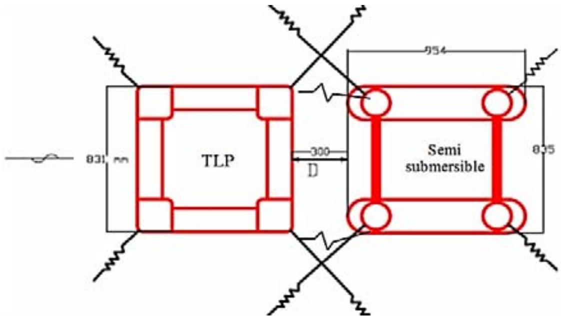

Figure 2: Layout TLP and semi-submersible model experimental set up (Dimension is in model scale).

Figure 3: TLP and Semi-Submersible set up into towing tank.

The models were attached to tow carriage by springs and regular waves generated by wave-maker at the end of towing tank (figure 3). At the start and end of these tests, the model was carefully held to prevent large offsets due to sudden wave exciting forces which could damage the mooring springs. The measurement starts to take when the wave height starts to become constant. In this model test, wave periods were carefully chosen to cover the models' natural period. The selected wave condition is shown in table 2.

Table 2: Input wave parameter for model test.

Wave Parameter					
No	Variable				
	T(s)	λ (m)	H(1/20) (cm)	H(1/40) (cm)	H(1/60) (cm)
1	1.25	2.44	12.2		
2	1.46	3.33		8.3	
3	1.65	4.25		10.6	
4	1.85	5.34		13.3	
5	1.97	6.03		15.1	
6	2.15	7.14		17.8	
7	2.50	9.39			15.6

4.0 CONCEPT OF GAP DISTANCE BETWEEN STRUCTURES

The gap distance between floating structures is assumed effected by the relative motion between two floating structures. In this study, the gap distance between floating structures which arrange in tandem arrangement is studied. Only surge motion is influence the gap distance between floating structures in this study.

The figure 4 showed that two floating structures arranged in a separate distance, l. Hence, the same wave will arrive at the in front structure to induce the motion before it is proceeded to induce the motion at behind structures. Therefore, leading phase between two structures is existed due to the time required by the wave travel from one structure to another structure.

From the theoretical point of view, the leading phase between structures can be calculated if the separate distance between structures and the wavelength, λ is known. The equation to calculate the leading phase between structures as follow:

$$\alpha = \frac{l}{\lambda} \times 2\pi \qquad (1)$$

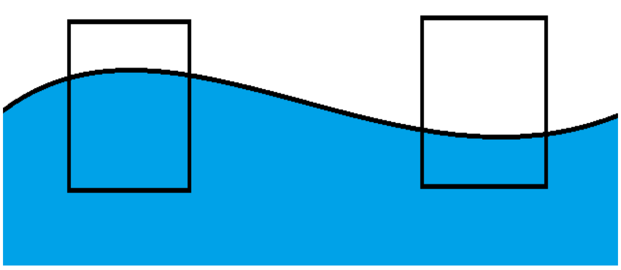

Figure 4: Progressive wave and Structure interaction.

The equation (1) shown that the leading phase between structures, α is in the ratio of structures separation distance, l to the wave length, λ.

Due to the arrangement of structure, it is obtained that wave arrived on structure (B) always leading by a phase, α respect to structure (A). Therefore, the motion on the structure (B) will always have a leading phase of α compare to structure (A). In this case, the surge motion of the floating structures can be represented as following equation.

$$X_A(t) = \bar{X}_A \sin(-wt + \beta_A) \quad (2)$$

$$X_B(t) = \bar{X}_B \sin(\alpha - wt + \beta_B) \quad (3)$$

Where $X_A(t)$ and $X_B(t)$ is the surge motion for structure (A) and structure (B), $\bar{X}_A$ and $\bar{X}_B$ is the surge amplitude for structure (A) and structure (B), β_A and β_B is the leading phase between wave to structure motion for structure (A) and structure (B), α is the leading phase between structures, w is the wave speed in rad/seconds and t is the time in seconds.

Next, the change of gap distance between two floating structures can be calculated based on the relative motion of the floating structures. The gap distance between two floating structures, $G(t)$ in tandem arrangement can be calculated by considered the original gap distance, $G_{initial}$, surge motion of both structures. The simplified equation as follows,

$$G(t) = G_{initial} + [X_A(t) - X_B(t)] \quad (4)$$

$$G(t) = G_{initial} + [\bar{X}_A \sin(-wt + \beta_A) - \bar{X}_B \sin(\alpha - wt + \beta_B)] \quad (5)$$

From the equation (4), it is obtained that the individual surge motion of the floating structures will contribute to the change of gap distance between floating structures when the wave progress pass through the floating structures.

Based on the equation (5), it is obtained that the gap distance is changed according to time. The minimum gap distance in the specific wave condition will depend on the response of the structures' motion response, wavelength and original gap distance. The function of the minimum gap distance between two floating structures possible to achieve can be represented in following function.

$$G_{min} \propto f(M_{struc-1}, M_{struc-2}, \lambda, G_{initial}) \quad (6)$$

Where G_{min} is the nearest gap distance between two floating structure achieved due to surge motion, $M_{struc-1}$ and $M_{struc-2}$ is the surge motion of structures 1 and structures 2 and $G_{initial}$ is the initial structures distance before the wave arrive.

5.0 EXPERIMENTAL DATA ANALYSIS

The experiment in this research is interested to find the possible minimum gap distance between two floating structures when the motion is induced by wave. The Qualisys Camera is used in the experiment to record the time domain position coordinate of the floating structures in wave tank. The changing of distance between two floating structure in time domain was calculated by considering the changing of position in the tank for both the TLP and semi-submersible respective to its original position. The equation to calculate the distance between two floating structures, $G(t)$ in the function of time, t, initial gap length, $G_{initial}$ and the amount of gap, $G(t)$ decrease in time as follow:

$$G(t) = G_{initial} + G(t) \quad (7)$$

where the amount of gap $G(t)$ decrease in time is calculated as follows:

$$G(t) = M_{struc-1}(t) - M_{struc-2}(t) \quad (8)$$

where, $M_{struc-1}(t)$ Is the position of in front structure which is TLP and $M_{struc-2}(t)$ Is the position of behind structure which is Semi-Submersible in this experiment. Zero position is located at the structures' individual initial position before advance by incident wave.

To obtain the minimum gap distance possible to achieve by the motion of both structures, the time domain gap distance data, $G(t)$ is converted to frequency domain, $G(F)$ to obtain the amplitude of the minimum gap length [25]. The relationship between the minimum gap distance with the structures' motion and wave condition is defining using the experimental data which converted to frequency domain.

6.0 MODEL EXPERIMENT RESULT

The regular wave experiment was conducted in head sea condition and the floating structures arranged in tandem arrangement. From the data recorded, the gap distance between floating structures was calculated by equation (8).From the conceptual study, it is obtained that the minimum achieved gap distance between floating structures is in the function $G_{min} \propto f(M_{struc-1}, M_{struc-2}, \lambda, G_{initial})$. Due to the experiment is only conducted in same initial gap distance, hence only the relationship between minimum achieved gap length with structures motion and wavelength is focused and discussed here.

The figure 5 and 6 showed the distribution of amount of gap length reduced verses the structure motion and summation of structures motion. From both the figure, it is obtained that the gap length between floating structures is reduced in the linear relationship to the individual structure motion and the summation of structures motion. From both the figures, it is clearly obtained that the larger structures motion will lead to closer distance between floating structures. This observation shown that the better mooring systems which can reduce the structure horizontal motions and help to reduce the possibility of clashing between floating structures.

From the finding, it can be represented the relationship between amount of gap distance decrease compare to initial gap distance is in the linear function to the structures motion where

$$G_{Reduce} \propto (M_{struc-1} + M_{struc-2}) \quad (9)$$

Since the structures motion in wave condition is often represent by the response amplitude operator, hence the above function can be written in the following format

$$G_{Reduce} \propto \left(RAO_{Surge_{struc-1}} + RAO_{Surge_{struc-2}}\right)\frac{W_H}{2} \qquad (10)$$

Also, the equation to link the amount of the gap distance can be reduced due to the structures motion can be written as an equation as follow

$$G_{Reduce} = C \cdot \left(RAO_{Surge_{struc-1}} + RAO_{Surge_{struc-2}}\right)\frac{W_H}{2} \qquad (11)$$

From the equation (11), the amount of gap reduced is assumed linearly to the structures motion. The constant C in the equation (11) is assumed involved the other variables which will affect the amount of gap length reduced due to structures motion. In the study, this constant C is defined from wavelength and structures arrangement.

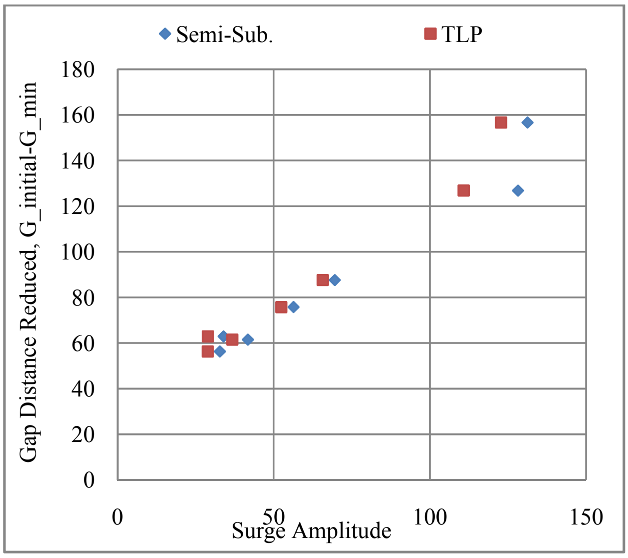

Figure 5: Comparison between surge amplitudes of TLP and Semi-submersible to the amount of gap length reduced respect to initial gap length.

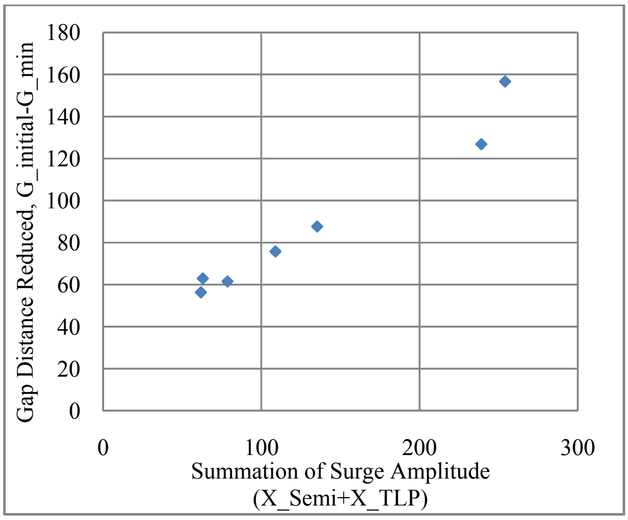

Figure 6: Comparison between amounts of gap distance reduced respect to initial gap distance to the summation of surge amplitude of TLP and Semi-submersible.

To study the effect of wavelength to the amount of gap distance can be reduced due to the structures motion, the figure 7 is plotted against wavelength in axis-x. The axis-y at figure 7 is equal to the amount of gap distance reduced divided by the total summation surge amplitude of both the semi-submersible and TLP.

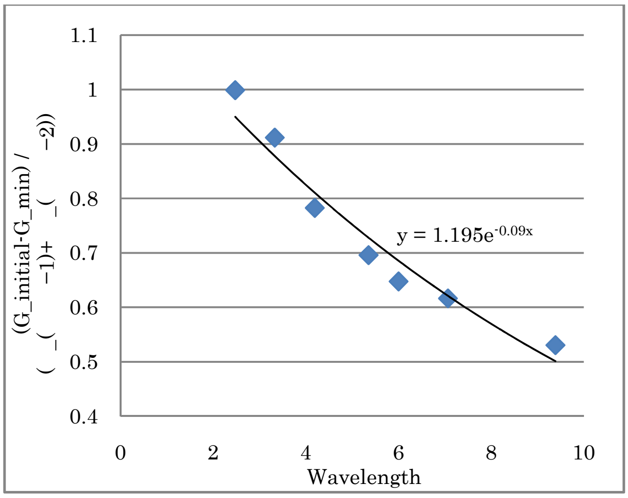

Figure 7: The tendency of ratio of amounts of gap distance reduced to wavelength.

From the figure 7, it is observed that the exponential curve is able to fix well with the experiment data. In this study, the equation to link both the axis-y and axis-x in figure 7 is

$$y = C_1 e^{C_2 x} \qquad (12)$$

Where, y is $(G_{initial} - G_{min})/(M_{struc-1} + M_{struc-2})$, x is wavelength, λ and C_1 and C_2 is the constant and in this arrangement and selected models the value is 1.195 and -0.093 respectively.

From the figure 7, it is showed that if the wavelength become longer, the amount of gap distance reduced due to the motions is lesser. This mean that the in very long wave condition, the reduction of gap distance between floating structures respectively to the initial gap distance become very less and the effect of gap reduced due to the motion of structure can be ignored.

To obtain the empirical equation which can be apply to predict the minimum gap distance between floating structures in wave induced condition, the equation (12) can be used and rearranged as follow:

$$y = C_1 e^{C_2 x} \qquad (13)$$

$$\frac{G_{initial} - G_{min}}{M_{struc-1} + M_{struc-2}} = C_1 e^{C_2 \lambda} \qquad (14)$$

$$G_{min=}G_{initial} - (M_{struc-1} + M_{struc-2}) * C_1 e^{C_2 \lambda} \qquad (15)$$

Also, from equation (11), we can rewrite the equation to include the structure response amplitude operator as follow

$$G_{min}=G_{initial} - \left(RAO_{Surge_{struc}-1} + RAO_{Surge_{struc}-2}\right)\frac{W_H}{2} * C_1 e^{C_2 \lambda} \quad (16)$$

7.0 DISCUSSION

From the Figure 8, the empirical equation showed well agreed with experiment's result. The comparison in Table 3 shown the percentage of difference between the result obtained by empirical equation and experiment is relatively small. The trend of change for the minimum gap to wavelength between both methods is similar as shown in the figure 8. The minimum observed gap length in this study is occurring at wavelength around 7.07meters. This is because both the floating structures experienced the largest surge motion in this wavelength.

In the comparison between experimental result and the empirical equation, it is observed that the introduced empirical equation (equation 16)can be fixed will with the experimental result directly measured from experiment. Based on the Table 3, the largest different between these two results is around 4.11%. This shown that the introduced empirical equation is fixed with the experimental result for this selected experiment model. However, to ensure the accuracy of the calculated result from the empirical equation, the RAO of the structures must be executed correctly. This is because the empirical equation is very sensitive with the RAO of both the structures.

The weakness in this empirical equation is the effect of the arrangement or initial distance between floating structures is no take into the consideration. This is because the experiment is only conducted for same initial gap distance. It is predicted that if the initial gap distance is changed, the constant, C_1 and C_2 in the equation (16) will change. Therefore, the accuracy of this empirical equation for other models is required to recheck.

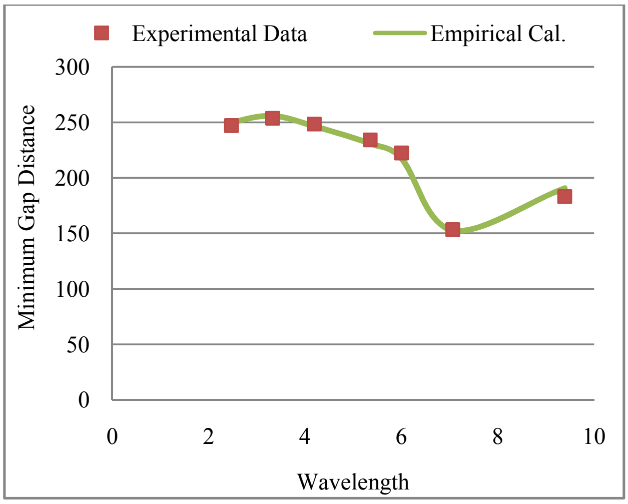

Figure 8: Predicted minimum gap distance between floating structures based on experimental data and empirical calculation.

In this study, the relationship between the amount gap distance reduced due to the structures motion and the wavelength is studied. From the experimental result, it can be observed the strong relationship is existed between the reduced gap distance with the structures motions and wavelength. To reduce the possibility of crash between structures, the structures horizontal plane motions should be properly control and analysis. Because the better control of structures motion is the initial step to avoid large change on the distance between floating structures.

Table 3: Comparison minimum gap distance predicted by empirical calculation to experimental data.

Wavelength, m	Percentage different between empirical and experimental result, %
2.48	1.27
3.33	0.85
4.20	0.83
5.35	1.41
6.00	2.20
7.07	0.46
9.39	4.11

8.0 CONCLUSION

In conclusion, this study has obtained that the gap distance reduced is strongly influence by the structures motion and wavelength. In this two floating structures system, the behavior of both the structures is required to consider when designing the structures arrangement. The strong relationship between the minimum achieved gap distance with the structures motion shows that the floating structures motion should be minimized especially in multiple floating structures system when both the structures are required to place close to each other such as during the LNG offloading operation. This target can be achieved by designed a more stiffness mooring system or avoided to operate the system in unfavour sea condition where the structures will experience the largest motions due to the progressive wave. The empirical equation introduced in this paper agrees with the experimental result. However, it is required to further study to involve the effect of different arrangement and structures models.

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